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ACIDIC PRECIPITATION IN ONTARIO STUDY

ANNUAL PROGRAM REPORT

FISCAL YEAR 1983-1984

APIOS Report No. 010/84

Prepared by the A.P.I.O.S. Coordination Office
Ontario Ministry of the Environment
November, 1984

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TABLE OF CONTENTS

Page

INTRODUCTION

Expanding industrial activity and continuing demand for energy in the early part of the century led to a rapid growth in emissions of several atmospheric pollutants including sulphur dioxide (SO_2) and nitrogen oxides (NO_x). As a result, in the late 1960s and early 1970s, governments became concerned about local ambient air quality. Ontario, along with many other jurisdictions, implemented air pollution abatement programs to effect improvements in local air quality.

In Ontario, average annual emissions of sulphur dioxide were reduced from 3.4 million tonnes in 1970 to 1.7 million tonnes in 1980.

In addition, in 1970, Ontario instituted the Air Pollution Index (API) Alert System. When unfavourable weather patterns occur, SO_2 and particulate emissions are ordered to be reduced before serious pollution episodes occur. Since establishing this Alert System, high air pollution episodes have been reduced drastically. For example, compared to 1970 levels, the 1983 annual average SO_2 level in downtown Toronto has been reduced by 94% (1970 - 0.71 ppm; 1983 - .004 ppm) and particulate matter has been reduced by 52%.

Even though substantial improvements had been made in ambient air quality, in the mid 1970s we became aware of damage to aquatic systems removed from local sources. We learned of the deterioration of lakes in south-central Ontario at about the same time as studies in the Adirondacks in New York State had identified acidic deposition from both distant and nearby sources as the cause for acidification of lakes in this region. Therefore, in 1979, Ontario established the Acidic Precipitation in Ontario Study (APIOS) to study the causes and effects of the long range transport of air pollutants.

The program addresses the acid rain problem in six major task areas and progress is reported under each of these tasks in the body of this report. The Committee Structure which has been developed to direct the study is shown in Figure 1.

During FY 1983/1984, Ontario's acid rain program focussed on analysis and interpretation of data collected in previous years.

At the same time, Ontario has continued to cooperate with her sister provinces and the federal government to ensure a coordinated Canadian approach. Through membership on several Federal/Provincial Committees, Ontario's research results contribute to the continued development and refinement of Canada's position on acid rain.

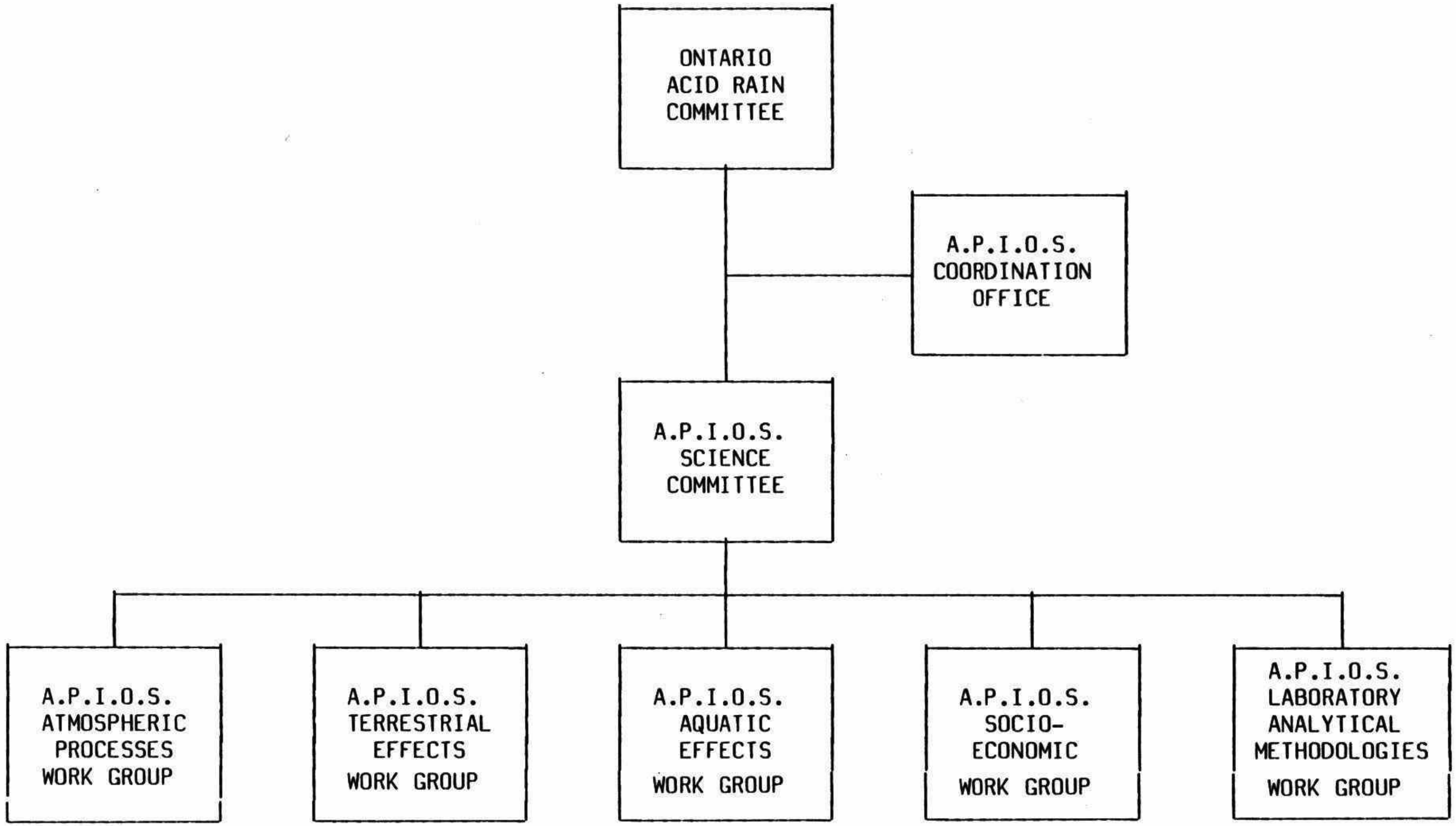
Ontario is involved in research on an international level as well. Canada and the United States have established a Committee to exchange information and to set up joint research projects. In addition, Ontario's researchers are involved in numerous joint projects with several European nations. (See Appendix I.)

Ontario plans to maintain its research program in order to precisely define the science of the problem; however, results to date continue to reaffirm our belief in the urgency of the problem and the need to undertake emissions reductions. Therefore, in the absence of an agreement with the United States, Ontario joined the other Eastern Canadian provincial governments and the Federal government on March 6, 1984 in a commitment to an SO_2 emissions cap of 2.3 million tonnes per year east of the Manitoba-Saskatchewan border by 1994. This represents a reduction of approximately 50% from the 1980 base case year when allowable SO_2 emissions were 4.6 million tonnes.

Research activities for FY 1984/1985 will continue in most areas but resources will be shifted to address high priority items such as forestry damage. A study of maple dieback is already in progress.

This issue is a very complex one since the current scientific consensus in Germany is that air pollution is a major factor in the extensive forest dieback occurring there. This means that other pollutants such as NO_x, hydrocarbons, ozone and heavy metals, which can also be transported long distances, may be involved as well.

FIGURE 1: A.P.I.O.S. COMMITTEE STRUCTURE



TASK #1 - ATMOSPHERIC PROCESSES STUDIES

A. Emissions Inventory

The compilation of statistics on the production of SO_2, NO_x and other pollutants serves several purposes. Trends in the emission of acid-producing gases are measured and matched with changes in deposition patterns. All of the atmospheric models require as input detailed information on SO_2 and NO_x emissions, by geographic location. Knowledge of the location and magnitude of emissions sources is also essential in planning cutbacks of acid gas emissions.

During FY 83/84, utility SO_2 and NO_x emission estimates for the U.S.A. in 1981 and 1982 were completed, as were preliminary estimates of SO_2 and NO_x for eastern North America. (See Table 1).

In a contract to the Ontario Research Foundation, a detailed summary of area (as opposed to point source) NO_x emissions was completed, and revised and updated by using more representative transportation data. Similar area emission estimates for SO_2, hydrocarbons, carbon monoxide, and particulates have been assembled, and were mapped and plotted. These area source data will be combined with point source data to provide more complete pollutant inventories for all of these substances.

TABLE 1

SO_2 AND NO_x EMISSIONS IN EASTERN NORTH AMERICA

(thousands of tonnes)

	1980		1981		1982	
	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
Eastern U.S.	21.0	13.2	20.5	13.2	19.5	13.0
Eastern Canada	3.9	1.1	3.7	1.1	3.1	1.1
Eastern N.A. (Total)	24.9	14.3	24.2	14.3	22.6	14.1

B. Modelling and Meteorology Studies

i) Atmospheric Modelling

Mathematical models combine our knowledge of the movement of air masses and the chemical transformation of pollutants during transport into a set of numerical equations. The output of the model can be compared to observed deposition patterns, and if the comparison shows a close agreement, we gain confidence that we have a good understanding of the causes and mechanisms involved in acid deposition. Once the models are sufficiently developed, emission reduction scenarios can be assessed by looking at resulting deposition patterns.

MOE has developed two models to address the long range transport of atmospheric pollutants. The Statistical model computes long term average pollution concentration and deposition, based on statistics of meteorological variables over many years. The Lagrangian model uses time-varying meteorological observations to compute the trajectories of puffs of pollutant, whose effects are summed over a specified period of time, such as a year or a season, to yield time-averaged pollutant concentration and deposition.

During FY 83/84, a major improvement was made in the Statistical model. Three years worth of air trajectories, initiated at three hour intervals from 60 source locations east of the Rocky Mountains were analysed (over half a million individual trajectories). The statistics from this analysis provided the base for a new "average" weather pattern for eastern North America, and were used to calculate the long term, long range transport and dispersion of air pollutants. The predicted contours of wet sulphate deposition now follow more closely the pattern of wet deposition derived from deposition monitoring data. A rigorous evaluation of the revised modelling results will continue in 1984/85.

The development of the Lagrangian model is now essentially completed. FY 83/84 saw the completion and incorporation of a method for handling the effects of precipitation variability over short space scales. Further development of a complex chemistry module for the model will be carried out under contract.

The Lagrangian model was used to simulate monthly average ambient concentrations and wet deposition of sulphur oxides over a three year period (1978, 1979 and 1980) on a grid array over North America. These years were the ones for which analysis of the meteorological statistics had been completed. The model produced monthly data on wet sulphate deposition which agreed very well with the wet sulphate measured in Ontario and some neighbouring States.

Also during FY 83/84, the Lagrangian model was used to estimate the effects of the Inco shutdown (between July, 1982 and March, 1983) on wet sulphur deposition at a number of locations in Ontario and the States.

Under a cooperative agreement with the State of Minnesota, copies of both the Statistical and Lagrangian models were transferred to the Minnesota Air Pollution Control Commission. A similar agreement with the State of New York resulted in a copy of the Statistical model being transferred to the New York State Department of Environmental Conservation.

Development of the Mesoscale model, which began in FY 82/83, continued in FY 83/84. This model is designed to provide information on a smaller geographic scale than the

Statistical model. The wind component of the model was completed in FY 83/84, and testing was initiated. Once the testing is complete, the wind model will be used to define mesoscale transport of pollutant puffs. The puff component is also being developed to include mesoscale processes which influence a region's air quality and pollutant deposition.

The most ambitious modelling exercise is the Eulerian, or Acid Deposition and Oxidants Model (ADOM). ADOM is a jointly-funded model being developed cooperatively by the Ontario Ministry of the Environment, Environment Canada, and the Federal Republic of Germany. This large project is progressing well, and all of the model components have now been developed. It will be used to assess various emission control scenarios, a task for which the usefulness of currently available models has been questioned. In FY 83/84, the model components were completed and transferred to the Canadian Meteorological Commission's Cray computer in Montréal. The U.S. Environmental Protection Agency is also developing an Eulerian model, and a protocol for cooperation in model development was agreed to in FY 83/84.

ii) Meteorological Data Acquisition System

The Meteorological Data Acquisition System (MDAS) is a computerized system which collects and stores meteorological data supplied by Environment Canada from its network of weather stations. By analysis of pressure and wind data, it is possible to calculate the path a "parcel" of air has travelled in the past few hours or days.

During FY 83/84, air trajectories for all precipitation events occurring in 1980 and 1981 were analysed to determine the compass sector of origin for the air parcels. The resulting report verified earlier findings: well over half of the sulphate, nitrate, and hydrogen ion loadings in Muskoka are associated with air parcels arriving from the south and southwest.

Also during FY 83/84, MOE assisted the Atmospheric Environment Service in providing "acid rain" bulletins to news media in Eastern Canada. Each week, all precipitation events at a number of sites are analysed chemically, and the trajectory associated with the air parcel which brought the precipitation is calculated.

MDAS also supplied the meteorological analysis of precipitation events during the Sudbury shutdown period of July, 1982 to March, 1983 in order to quantify the effect of the "Sudbury plume" on precipitation and air quality in Ontario.

The computerized plotting facilities of MDAS are also being used in support of mapping water and soil chemistry data across Ontario.

C. Deposition Monitoring Networks

A new sampling station was established on Otter Island, in Pukaskwa Park on the northern shore of Lake Superior. The MOE Northwestern Region has found acidified lakes in the Park, and the new station will supply results on the deposition chemistry in the area.

The analysis of "dry-side" buckets from the Sangamo samplers was discontinued. A Sangamo sampler consists of two buckets, lined with plastic bags. During dry weather, one of the buckets is exposed, but during rain events, a moisture-activated switch causes a lid to move over the "dry" bucket, and exposes the "wet" side to precipitation. An intensive quality assurance analysis of "dry" deposition data had led to the conclusion that the sampling techniques did not provide meaningful data.

Furthermore, as a result of the quality assurance audit, several sampling sites were abandoned, and some new ones were selected in accordance with the revised siting criteria.

Precipitation chemistry and air quality data up to the end of 1981 were tabulated, analysed, and reported during FY 83/84. The data reveal that all of southern Ontario continues to receive wet sulphate loadings well in excess of 20 kg/ha·yr, a loading considered to be the maximum for the protection of most surface waters against acidification.

Considerable effort was expended in the analysis of deposition data to determine the effect of the Sudbury shutdown on precipitation quality.

D. Laboratory Support

Laboratory support for the Deposition Monitoring Program accounted for 81,891 analyses. A special study on sample integrity was undertaken, involving immediate analysis of precipitation events for certain chemical components, to determine if accuracy is affected by delays to analysis.

Analytical development continued, with a new procedure for preservation coming on line and preliminary work on the use of X-ray fluorescence as an analytical technique for low volume filters being initiated.

Finally, participation in interlaboratory comparative analysis studies continued, and the quality assurance program became fully operational.

TASK #2 - AQUATIC EFFECTS STUDIES

A. Limnology Studies

i) Lake and Stream Chemistry Models

The development of water chemistry models for lakes and streams is vital as a means of assessing our understanding of the acidification of the aquatic environment. This is important since it provides a tool for predicting either the effects of abatement measures, or the further deterioration of impacted aquatic systems should abatement measures be delayed.

A good understanding of aquatic systems is also important in making an assessment of the size of Ontario's aquatic resource at risk due to acidification. Because Ontario has such a large number of lakes, it is not possible to conduct intensive monitoring studies on any more than a small percentage of them. The development of aquatic models and a documentation of biological effects associated with acidification will provide the basis for extrapolation of this knowledge so that predictions can be made of the effects of acidification on systems not being monitored.

A data base of the watershed and hydrological characteristics of the Dorset calibrated watersheds has been compiled. This will provide the requisite information for a model to predict the loss of chemicals from watersheds in general. The loss of total phosphorus as a function of watershed characteristics has already been successfully modelled under the Lakeshore Capacity Study, and a similar approach is being used to study the loss of other chemicals, such as calcium and alkalinity.

Computing facilities and more personnel were transferred to the Dorset Research Centre. Several hydrological models (lake evaporation, areal evapotranspiration and streamflow), developed jointly with the Water Modelling Unit, were implemented on the Dorset computer. Dr. Hans Martin Seip, from Norway, spent his sabbatical in Dorset. With his assistance, a version of the "Birkenes-Storgama" stream water chemistry model was developed and implemented. Refinements on this model are continuing.

The lake chemistry model also underwent continued development during FY 83/84. Application of the model to data series from two of the Dorset lakes, Harp and Red Chalk, were carried out.

ii) Biological Studies

Stream invertebrate populations were studied as part of a stream acidification experiment during FY 82/83. In this experiment, sections of a stream near Dorset were acidified with sulphuric acid. The response of the stream

invertebrates to the acidification was monitored, and intensive chemical sampling was conducted, with analytical support being provided by the mobile laboratory. The results of this experiment are currently being analysed and compared with similar ones conducted in Northwestern Ontario and New Hampshire.

iii) Calibrated Watersheds

Results of preliminary analysis on long term trends in lake alkalinity and major ions continued, as well as an analysis of the interaction of acid deposition on the bioavailability of phosphorus in streams.

A major advance in the understanding of the role of organic acids in controlling pH was achieved. Using a modification of an approach developed by scientists at the Canada Centre for Inland Waters, dissolved organic carbon measurements were used to estimate the concentration of natural organic acids in an inflow to one of the Dorset lakes. By estimating the organic acid concentration, and the degree of dissociation of these acids, the relative contribution of natural and anthropogenic acids to total water acidity was determined. The results of the analysis indicated that pH depression in the spring was caused by sulphuric acid, while during the summer months, organic acids controlled the water pH in the stream. The only source of sulphate in the watershed is atmospheric input.

Spring runoff is a time of intensive sampling activity on the calibrated watersheds, and FY 83/84 was no exception. The spring of 1984 was characterized by a double runoff; the first runoff was followed by a freeze and further snow accumulations. The double runoff generated an unusually heavy sample load. Automatic samplers were used on four of the streams to allow frequent sampling around the clock.

B. Taxonomy Studies

i) Filamentous Algae

Lake acidification produces noticeable alterations in planktonic and benthic algal communities. In particular, some kinds of filamentous algae are favoured by acidic conditions. In a cooperative study with the federal Department of Fisheries and Oceans, algae populations were monitored during the experimental acidification of two lakes in Northwestern Ontario. The results of these cooperative studies are the subject of a report in preparation which will include results of work done in 1984.

Field work included a mapping of the distribution and density of benthic algae in one of the experimentally acidified lakes, and mapping of filamentous algae

distribution in Muskoka-Parry Sound area lakes, including Bowland Lake, which has been experimentally neutralized.

ii) Odour Production

Another change in algae that sometimes occurs in softwater and acidic lakes is a population explosion of algae that produce an intensely disagreeable odour. The organism that is responsible is *Chrysochromulina breviturrita*, which was first described by MOE scientists in 1978. Since then, the alga has been found in many areas of northeastern North America, and reports of odour problems have come from Massachusetts and New Hampshire, as well as Ontario.

The condition which triggers the "bloom" of *C. breviturrita* associated with odour problems is still uncertain. Interviews with long-time local residents indicate that it is a recent problem, and by all accounts, such a bloom is a very memorable event. FY 83/84 was the third year of investigation on 12 lakes in the Muskoka-Haliburton area, several of which have had odour problems. It is hoped that these limnological studies will isolate the factors contributing to the sporadic blooms.

Complementary research is being conducted under contract at the University of Western Ontario. In FY 82/83, the first successful laboratory cultures of *C. breviturrita* were established. During FY 83/84, the cultures were rendered bacteria-free, and some odour production occurred. Future work will include establishment of the culture on an artificial substrate, and definition of the chemical conditions which favour odour production.

Another species of algae capable of producing odour is *Synura*. Between 1976 and 1984, there were eleven instances of odour problems in drinking water supplies. The incidents all occurred in softwater Precambrian Shield lakes, and were favoured by lower pH. Incidents of this kind may become more frequent if significant pH drops occur in softwater lakes.

iii) pH Change and Algal "Fossils" in Lake Sediments

The study of algae and diatom communities in acid lakes has some interesting applications. Diatoms and some types of algae (chrysophytes) leave remains in the sediment which do not decompose. By carefully characterizing the diatom or chrysophyte communities in a number of lakes over a range of pH's, a "calibration" can be developed which relates the two. This calibration can then be applied to the chrysophyte or diatom remains in a sediment core, and the pH history of the lake can be reconstructed.

Diatom populations from a series of 35 lakes in a pH range of 4.5 to 7.5 were characterized, and a preliminary

calibration for Ontario Precambrian Shield lakes was developed. The calibration was tested on a sediment core from a neutral clearwater lake. The analysis indicated that the lake pH had not changed for about 250 years. Similar analyses are planned for two acidic lakes in 1984.

An alternative to diatom dating is the use of silicate scales from chrysophyte species. This approach looks promising, since chrysophyte species are much less numerous than diatom species, so the characterization process should be considerably simplified. The past years' efforts have been directed at clarifying the taxonomy of chrysophytes in Ontario lakes, and work has begun on the development of a chrysophyte calibration.

C. Ground Water Studies

i) Contribution to Lakes and Streams

Depending on the nature of a watershed, ground water may be a major contributor to both the quality and quantity of water being exported from the watershed. Studies to date indicate that the chemistry of ground water is significantly different from precipitation or lake water.

Current work in this area is designed to quantify the chemical inputs to a lake associated with ground water. Work during FY 83/84 centred on three of the "calibrated" lakes in the Dorset area: Harp, Plastic and Dickie.

Also included were geophysical surveys on two of the Harp Lake watersheds. The extent, depth and composition of bedrock and overburden was mapped. This mapping will assist in the placement of ground water sampling devices in these watersheds.

ii) Ground Water Quality Inventory

The extensive survey of ground water acidity continued. One area covered in this year's work was between Timmins and Sault Ste. Marie. Of 43 domestic wells sampled, four had a pH below 6.0. A similar survey in the Parry Sound area revealed 4 of 28 wells with pH less than 6.0.

Low pH in all of the wells tested so far is due to dissolved carbon dioxide, not acid deposition. Nonetheless, low pH water supplies can be quite corrosive, and leach metals out of plumbing systems. On occasion, metal levels in excess of drinking water criteria have been measured. Elevated metal levels are usually found in water that has been in contact with the plumbing for long periods, and metal levels fall rapidly as the plumbing system is flushed.

Cottages which draw water from low pH lakes face similar problems. Sixteen cottages on eight lakes in the Sudbury area were the focus of a study which determined changes in the quality of tap water after various flushing periods.

D. Fish Toxicity Studies

i) Laboratory Studies

The combination of high acid and aluminum levels will kill fish. Even at levels below this "toxic threshold", fish can be severely stressed. Work to date has studied this stress mechanism and characterized it in terms of chemical and biological responses in the fish. Work this year focussed on the role of organic acids in modifying these stress reactions. Organic acids can complex aluminum ions and render them considerably less toxic.

Work has also continued on defining the exact toxic threshold for different species, and different life stages of these species.

This year, walleye and white sucker eggs were exposed to a range of acid and aluminum concentrations in the presence of organic acids. Egg and fry mortality at various life stages were recorded. From work to date, it appears that fish fry as they emerge from the eggs constitute the most sensitive life stage, although the lethal threshold of pH and inorganic aluminum varies considerably from species to species.

A study at the University of Toronto on the effect of lowered pH on winter survival of young-of-the-year (YOY) smallmouth bass was finished this year. This study was funded by the Ministry of Natural Resources. Smallmouth bass do not feed during the winter, and studies to date indicate that seven day exposures to a pH less than 4.5 causes death in overwintering YOY bass. Longer term (42 days) exposure to pH less than 5.0 causes stress and mortality of some overwintering YOY bass. Small fish are more susceptible than large fish.

ii) Field Studies

In experiments parallel to the laboratory studies, walleye and white sucker eggs were exposed at fifteen sites in the Dorset area. The water was sampled frequently, and the mortality rates observed in the field will be compared to the mortality recorded in the laboratory. The current hypothesis is that low pH and high aluminum are responsible for most mortality. By comparing the results of field and laboratory bioassays, this hypothesis can be tested. If mortality is significantly higher or lower in the field, factors that may mitigate or exacerbate the combined effects of acid and aluminum may be isolated.

The Ministry of Natural Resources continued its investigation of the collapse of a white sucker population in Westward Lake in Algonquin Park. There has been no successful recruitment in this population for about five years, although the water chemistry in the lake (pH 6.0) should not be toxic to sucker eggs or fry. During the spring of 1983, sucker eggs were incubated in Westward

Lake water, and evidently hatched successfully. A longnose sucker population in a lake near Dorset may be undergoing a similar phenomenon. Further studies are planned to try and isolate the cause of the population failure.

Other studies by MNR include an evaluation of the influence of ground water on the survival of brook trout eggs and fry. Brook trout seem to prefer areas of ground water upwelling to spawn, and the water chemistry in these upwelling zones typically has much higher pH and alkalinity than surrounding areas. Ground water sampling devices were installed in some brook trout spawning areas to evaluate this effect.

The results of cooperative MNR/MOE studies on lake trout spawning shoals in Whitepine Lake north of Sudbury have shown that water chemistry in the near shore zones can be extremely variable. In particular, aluminum levels may vary considerably between water above spawning shoals and water taken from the interstices of rubble where the eggs are deposited, and the fry emerge. An evaluation of potential effects of acidification on fish populations must take this into account. If fish frequent near shore zones during the spring, they may be exposed to more severe conditions than if they stay in deeper water. MNR has initiated a study to examine the inshore distribution of fish during the spring.

A cooperative study conducted by MNR, MOE and the federal Department of Fisheries and Oceans included the survey of 65 lakes in four secondary watersheds. The data from these surveys are being used to examine biological and chemical linkages between lakes, and the relationships between fish community composition and the physical and chemical characteristics of the lakes.

Studies conducted by MNR on 24 lake trout lakes which span a range of water chemistry show that the abundance of lake trout declines at pH levels below 5.5. No lake trout were caught in the lakes with pH below 5.2. Examination of the population structure suggests recruitment failure as the cause for the extinction of lake trout.

E. Extensive Lake Sampling

This program is carried out in cooperation with the Ministry of Natural Resources, and is designed to delineate the magnitude of Ontario's aquatic resource at risk due to acidification. The results of sampling over 4,000 lakes in the province were published and a summary is shown in Tables 2 and 3.

The majority of the acidified lakes are in an elliptical area around Sudbury, stretching to the northeast and southwest of the city. However, an increasing number of acidified lakes are being identified in other areas of the

TABLE 2: Summary of the Number of Lakes in each Alkalinity Class by County or District and for Ontario

County or District	Number of Lakes in each Alkalinity Class					Total No. of Lakes Evaluated
	Acidified (0 ueq L^{-1})	Extreme Sensitivity (0 to 39.9 ueq L^{-1})	Moderate Sensitivity (40 to 199 ueq L^{-1})	Low Sensitivity (200 to 499 ueq L^{-1})	Not Sensitive (500 ueq L^{-1})	
Algoma Dist.	19	59	204	91	78	451
Bruce Co.	.	.	.	.	7	7
Cochrane Dist.	1	3	6	13	81	104
Durham Co.	.	.	.	.	1	1
Frontenac Co.	.	.	1	10	63	74
Grey Co.	.	.	.	.	3	3
Haliburton Co.	5	86	113	31	23	258
Hastings Co.	.	.	35	20	50	105
Huron Co.	.	.	.	.	1	1
Kenora Dist.	.	1	78	86	95	260
Lanark Co.	.	.	.	1	37	38
Leeds Co.	.	.	.	.	32	32
Lennox & Addington Co.	.	4	26	19	39	88
Manitoulin Dist.	20	20	1	1	5	47
Middlesex Co.	.	.	.	.	1	1
Muskoka Dist.	2	47	108	6	11	174
Nipissing Dist.	9	74	352	78	4	517
Northumberland Co.	.	.	.	.	1	1
Parry Sound Dist.	7	50	121	14	1	193
Peel Co.	.	.	.	.	1	1
Peterborough Co.	.	2	7	6	40	55
Prince Edward Co.	.	.	.	.	9	9
Rainy River Dist.	.	13	147	54	32	246
Renfrew Co.	3	28	164	86	56	337
Simcoe Co.	.	.	7	.	10	17
Stormont Co.	.	.	.	.	1	1
Sudbury Dist.	71	98	124	56	74	423
Thunder Bay Dist.	4	20	105	123	160	412
Timiskaming Dist.	14	17	27	31	35	124
Victoria Co.	.	.	21	1	12	34
York Co.	.	.	.	.	2	2
Provincial Total	155	522	1,647	727	965	4,016

TABLE 3: Summary of the Percentage of Lakes in each Alkalinity Class by County or District and for Ontario.

County or District	Percentage of Total Number of each Alkalinity Class					Total No. of Lakes Evaluated
	Acidified (0 ueq L^{-1})	Extreme Sensitivity (0 to 39.9 ueq L^{-1})	Moderate Sensitivity (40 to 199 ueq L^{-1})	Low Sensitivity (200 to 499 ueq L^{-1})	Not Sensitive (500 ueq L^{-1})	
Algoma Dist.	4.2	13.1	45.2	20.2	17.3	451
Bruce Co.	.	.	.	.	100.0	7
Cochrane Dist.	0.9	2.9	5.8	12.5	77.9	104
Durham Co.	.	.	.	.	100.0	1
Frontenac Co.	.	.	1.4	13.5	85.1	74
Grey Co.	.	.	.	.	100.0	3
Haliburton Co.	1.9	33.3	43.8	12.0	8.9	258
Hastings Co.	.	.	33.3	19.0	47.6	105
Huron Co.	.	.	.	.	100.0	1
Kenora Dist.	.	0.4	30.0	33.0	36.5	260
Lanark Co.	.	.	.	2.7	97.4	38
Leeds Co.	.	.	.	.	100.0	32
Lennox & Addington Co.	.	4.5	29.5	21.6	44.3	88
Manitoulin Dist.	42.6	42.6	2.1	2.1	10.6	47
Middlesex Co.	.	.	.	.	100.0	1
Muskoka Dist.	1.1	27.0	62.1	3.4	6.3	174
Nipissing Dist.	1.7	14.3	68.1	15.1	0.8	517
Northumberland Co.	.	.	.	.	100.0	1
Parry Sound Dist.	3.6	25.9	62.7	7.3	0.5	193
Peel Co.	.	.	.	.	100.0	1
Peterborough Co.	.	3.6	12.7	10.9	72.7	55
Prince Edward Co.	.	.	.	.	100.0	9
Rainy River Dist.	.	5.3	59.8	22.0	13.0	246
Renfrew Co.	0.9	8.3	48.6	25.5	16.6	337
Simcoe Co.	.	.	41.2	.	58.8	17
Stormont Co.	.	.	.	.	100.0	1
Sudbury Dist.	16.8	23.2	29.3	13.2	17.5	423
Thunder Bay Dist.	1.0	4.9	25.5	29.9	38.8	410
Timiskaming Dist.	11.3	13.7	21.8	25.0	28.2	124
Victoria Co.	.	.	61.8	2.9	35.3	34
York Co.	.	.	.	.	100.0	2
Provincial Total (number of lakes)	3.9 (155)	13.0 (522)	41.0 (1,647)	18.1 (727)	24.0 (965)	4,016

province, including Algonquin Park, Muskoka-Haliburton, Algoma, and Parry Sound. Mostly, these acidified lakes are small headwater lakes, but their distance from point sources implicates long range transport of acids as the cause of acidification.

Another result of the extensive lake survey has been the identification of three acidified lakes in Pukaskwa National Park, in Northwestern Ontario. These are the first acidified lakes found in this region, and they are unique in Ontario since they appear to be being acidified by a fairly low rate of wet sulphate deposition. Many of the lakes in the Park are extremely sensitive, and a careful monitoring program of lakes and streams in the Park is continuing.

Low rainfall was accompanied by a summer alkalinity increase in many of the Pukaskwa lakes, including two of the acidified ones. During the summer and fall, these lakes had slightly positive alkalinities. Plans were made to study the relative role of organic and anthropogenic acids in controlling the pH of these lakes.

Lake surveys included 147 lakes in Hastings County and the Nipissing District, and approximately 500 lakes sampled by MNR in northern Ontario. The results of these surveys will be incorporated in an updated version of the lake sensitivity surveys.

During FY 82/83, a number of lakes around the Sudbury area were also sampled. Most of these lakes had been sampled between 1974 and 1976. Many of the lakes close to the Sudbury smelters show signs of significant improvement. This is seen as a very encouraging result, since it strongly suggests that abatement of sulphur dioxide will result in tangible improvements in the water quality. The degree of improvement in the lakes in the Sudbury area was correlated with their proximity to the smelter.

F. Remedial Methodologies Development

Recognizing that lake neutralization is at best a temporary measure to delay or reverse the effects of acidification, Ontario is pursuing the development of lake neutralization expertise as a method of protecting and rehabilitating lakes. Even under the most optimistic of emission abatement scenarios, the significant reduction of acid inputs into many of Ontario's lakes is several years away. Lake liming may prove to be a feasible interim measure for the protection of important gene pools, or the rehabilitation of significant sport fisheries.

During FY 83/84, three lakes were under study: Bowland Lake, an acidic lake 70 km north of Sudbury, and Trout and Miskokway Lakes, acid-stressed lakes near Parry Sound.

This year, the first of two whole-lake neutralizations occurred. Bowland Lake was neutralized with 85 tonnes of finely powdered calcite. The limestone was applied in August by a Canso water bomber, and the pH of the lake was raised from about 5.1 to approximately 6.8. Prior to neutralization, Bowland Lake water was toxic to lake trout. Yellow perch still existed in the lake in a numerous but stunted population. The indigenous lake trout and white sucker populations had disappeared in the late 1960's, and repeated efforts to stock the lake had failed.

After neutralization, fingerling, yearling and adult lake trout were introduced to the lake. Capture of some of these trout in the spring indicated that they had survived over winter. Several of the adults had radio transmitters implanted in them, and these trout will be followed in the fall of 1984 to determine if spawning is attempted.

One of the acid-stressed lakes, Trout Lake near Parry Sound, is scheduled for neutralization in 1984. This lake and Miskokway Lake, another acid-stressed lake, were the subject of fisheries assessment work and intensive chemical monitoring during FY 83/84, particularly in the spring melt period.

The lake neutralization study is a joint MOE/MNR program being coordinated by a private company, Booth Aquatic Research.

G. Laboratory Support

Task #2 continues to generate the largest sample load in A.P.I.O.S. A total of 261,320 analyses were performed. Periodic backlogs continue to be a problem, particularly during the spring. This season sees extremely heavy sampling during snowmelt, as well as sampling in support of laboratory and field bioassays.

The mobile laboratory was used for a pH/acidity survey of private wells in the Muskoka-Haliburton area. The lab was also stationed near Bowland Lake for much of August to provide analytical support for the intensive pre- and post-liming surveys of the lake.

Experience with aluminum has shown that the chemical species of an element in water can be more important than the absolute amount. Development work began on methods to determine the speciation of manganese and zinc in natural waters.

TASK #3 - TERRESTRIAL EFFECTS STUDIES

A. Vegetation Studies

i) Lichen and Moss Study

Lichens obtain virtually all of their nutrients from the air and from precipitation. Because of this, they have been used as air quality indicators, since their chemistry reflects atmospheric deposition. During FY 82/83, over 200 lichen samples were taken across the province, and characterized chemically. During FY 83/84, much of this data was mapped, and preliminary assessment is underway.

Also during FY 83/84, inventories of lichen and moss distribution at each of the biogeochemical sites were completed. Photometric plots of lichens on three tree species at each site were established so that growth rate at each site can be determined.

ii) Experimental Studies with Acid Rain

A continuing study in this area is the experimental assessment of the sensitivity of important crops to acid rain. Experiments are conducted in rain chambers, where plants can be placed and receive rain of known chemical composition.

Four varieties each of alfalfa, barley, soybean, and cabbage were subjected to rain treatments which simulate varying degrees of acidity. The results of these experiments are being statistically analysed. One complication in this type of research is the large number of strains or cultivars of commercially important species. Agricultural research produces these cultivars optimized for yield under a wide variety of climatic and soil conditions, and work to date has revealed that different cultivars react quite differently to acid rain simulants. On occasion, a cultivar will be out of favour with farmers by the time the experiments are complete. Another complicating factor arises from the fact that since the crop cultivars have been continuously selected for good yield under ambient conditions, a fair amount of genetic selection for resistance to air pollution and acid deposition may have already occurred.

Most crop cultivars show a stimulation under moderate treatments of simulated acid deposition, and a decrease in yield under stronger acid treatments. One hypothesis explaining these results involves two counteracting effects: a negative effect from the sulphate component of acid deposition, and an effect from the nitrate component that stimulates crops up to a certain point, and then exerts a negative influence. Under ambient conditions in Ontario, it is likely that acid deposition has a slight stimulatory influence on crops.

A major focus of activity was the construction of the mobile exclusion canopy system. This consists of three greenhouse-type canopies that can move on tracks. When a sensor system detects precipitation, these canopies will move over crops, and nozzles built into the canopies will apply rain of different pH's to crop plots under the canopy. The amount of rain applied will be the same as the amount falling outside. In this way, the crops will be exposed to identical growing conditions, and only the chemistry of the rain will vary. Another feature of the system is a set of perforated plastic pillows through which filtered air can be blown between the rows of crops. When a pollution episode with high levels of SO_2, NO_x or ozone is detected, filtered air can be forced through the pillows to decrease the pollutant levels in the vicinity of the crops. The same system can be used to artificially enhance concentrations of individual pollutants, or combinations of pollutants as well.

During FY 83/84, considerable effort was expended on finalizing the design of the canopies, testing the rain mixing and delivery system, and writing the necessary control software. The system will be ready for the 1984 growing season, and will hopefully be completely automated.

iii) Maple Dieback Study

This is a new component of the A.P.I.O.S. program. Complaints were received from the town of Prescott about unusual death and damage to maple trees in the town. A team from the Phytotoxicology Section was sent to investigate, and confirmed that unusual maple mortality was indeed occurring. A preliminary assessment pointed towards a drought stress, since maples on a golf course which received regular irrigation did not appear to have the same mortality. Insect infestation and disease were not apparently involved.

Trees can be subject to a number of stresses: drought, severe winters, insect infestations, fungi, diseases, parasites, and air pollution alone or in combination may damage or kill a tree. Assigning tree damage to one specific cause is very difficult. For example, a tree may succumb to drought if it has an additional stress placed on it due to air pollution. In the absence of the pollution, the tree may have survived the drought.

It became apparent that maple dieback was not restricted to Prescott. Complaints from the public, and from people involved with maple syrup production indicated that unusual maple mortality was occurring in many parts of southern Ontario, and a program was designed to assess the role of acid deposition or other air pollutants in the maple dieback syndrome.

In cooperation with the Ministry of Agriculture and Food and the Maple Syrup Producers Association, a number of woodlots where significant dieback was occurring were identified. During the summer and fall of 1984, these woodlots will be visited, and soil, foliage, roots, and tree core samples will be taken. The incidence of damage, management practices, histories of insect infestations or disease, and other relevant information will be gathered in an attempt to identify the cause of the syndrome.

B. Soils Studies

i) Baseline Soil Study

There is a large amount of data on soils in Ontario, but it is difficult to use this data to assess the sensitivity of soils to acidic precipitation. Most of the soil data available is on agricultural soils which have been modified by fertilizer application and are no longer representative of the native soil. Another problem is that past analyses of soil have been conducted using a variety of sampling and analytical techniques that are not always comparable to contemporary methods.

The purpose of the soil baseline study was to provide a soil data base for Ontario, using standardized sampling and laboratory methods. This will provide the basis for further resampling of the sites and will permit mapping of Ontario soils according to various soil sensitivity criteria.

The baseline soil sampling is now completed. Since 1980, 3400 samples from 400 sites around Ontario have been collected, and over 88,000 analyses have been performed.

A preliminary report tabulating the soil characteristics and composition of all the sample sites was published. Future plans include an attempt to map the province based on soil sensitivity criteria which are being derived experimentally.

The ability to detect chemical changes in soil caused by acidic precipitation is limited by the chemical variability of the soil. A soil variability study is being conducted to examine the spatial and seasonal variation of soil characteristics, at the two southern Ontario biogeochemical sites. The results of this study will be crucial in differentiating between changes in soil chemistry which are due to natural variation, and changes which might be attributable to acidic precipitation.

ii) Soil Column Experiments

Two laboratory experiments are being conducted on soil columns. The first uses three soil types, each of which is divided into horizons and combinations of horizons. Simulated acid rain at pH 5.6, 4.2, and 3.0 is being

applied at 500 ml per week, almost double the natural rate in southern Ontario. The water passing through the columns is analysed monthly for a number of parameters.

A similar set of columns was set up in Thunder Bay's Lakehead University Laboratory, using soils typical of Northwestern Ontario. Lakehead University is under contract to the MOE to perform the research at the Hawkeye Lake biogeochemical site.

This long-term experiment has indicated so far that under continued acid loadings, certain types of soils common in Ontario (podzols and brunisols) may eventually be stripped of base cations. All of the sulphate added to the soil is being retained in the lower soil horizons. As the upper horizons become saturated with sulphate, base cations are being removed, and metals such as aluminum are being mobilized.

iii) Soil Buffering

One measure of the sensitivity of a soil to acidification is to assess its buffering capacity. Buffering capacity is essentially a measure of the resistance a substance or solution has to a change in pH. In FY 83/84, the buffering capacity of a number of soils from baseline soil sites across Ontario was assessed.

All surface soils showed the ability to buffer low and moderate additions of acid. At higher acid additions the surface horizons of clay soils (or Luvisols) became only slightly acidic. Sandy soils that are naturally moderately acidic (Brunisols) had pH drops of 1.0 to 1.5 in their surface horizons. The organic portions of Podzols, which are naturally quite acidic, showed the least change in pH.

The type of acid added affected the results. In general, larger pH drops were observed when nitric acid was added, and smaller changes occurred when sulphuric acid was used. It should be noted, however, that these experiments used much higher amounts of acid than those found in naturally occurring precipitation in Ontario. Most of the surface soils showed a capacity to buffer acid amounts equivalent to 25 years of deposition at current rates.

C. Biogeochemical Studies

The purpose of the biogeochemical studies is to measure the input, export, and internal cycling of nutrients and metals in forested ecosystems. The calibrated watershed studies under Task 2 are designed to construct nutrient and metal budgets for lakes and streams; the biogeochemical studies extend these budgets to the terrestrial watershed.

This was a year of continued development for this study. It marked the second full year of sampling at the southern sites at Harp and Plastic Lakes in the Muskoka-Haliburton region. The two northern sites became fully operational. One of the northern sites is at High Falls, near Sudbury, and the other site is at Hawkeye Lake, near Thunder Bay. In FY 82/83, the northern sites had been selected and weirs installed on the streams. FY 83/84 saw the installation of the sampling equipment, and the first full year of sampling.

At each of the sites, watershed mapping and forest inventories are done. The aqueous output of the watershed is measured by chemical sampling of the stream, and a calibrated weir. Deposition monitoring is done by sampling from a platform above the forest canopy. Soil is mapped and analysed, and water flowing through the soils is collected by lysimeters.

Lysimeters are porous ceramic discs, sealed with plastic on all but one face. A tube is imbedded in the plastic so that liquid may be drawn through the disc. One problem with lysimeters is that a small vacuum is needed to draw soil water through the disc and into the tubes. A major innovation was developed by the contractors at the Dorset biogeochemical site (University of Toronto Forestry), which facilitates the use of lysimeters in the field. A large tank is evacuated periodically with a portable vacuum pump, and connected via valves, tubes, and manifolds to the lysimeters. This permits the unattended collection of soil leachate samples in the field.

Other components of the biogeochemical study sampling scheme are throughfall, stemflow, and litterfall samples. Preliminary results from the Dorset sites show that vegetation can significantly alter the chemistry of precipitation. For example, the pH of throughfall is raised by deciduous trees, and decreased by coniferous trees (throughfall is rain that contacts the forest canopy). Stemflow, which is rain that flows down tree trunks, is also altered significantly. Hemlock stemflow can be as low as pH 3.0, while deciduous stemflow is frequently as high as pH 6.0.

Litterfall is simply the leaves, twigs, seeds, and other organic debris that fall from trees to the forest floor. Chemical analysis of litterfall will give a measure of nutrient input to the forest floor not associated with meteorological deposition. Litter decomposition rates are determined by deploying nylon mesh bags containing leaf and needle litter from the major tree species. Replicate bags are collected, weighed, and analysed periodically.

Investigations also include documentation of element storage in the biomass and soil. Biomass sampling included the analysis of whole trees. Roots were excavated with high pressure hoses, and samples of roots,

bark, trunk, branches, leaves and twigs will be analysed to provide an estimate of element storage in trees. Soil surveys have been conducted to identify soil types in the basins. Chemical analysis of soils from selected locations provide estimates of element reserves in the soil.

In combination, these measurements will be used to construct a model which will describe how deposition chemistry is altered in the terrestrial ecosystem before it enters lakes and streams as surface runoff or groundwater. In addition, the internal cycling pathways for the forested ecosystems will be quantified. Because sampling and analytical methods are uniform at all the sites, it is hoped that differences attributable to precipitation chemistry can be isolated.

D. Laboratory Support

During FY 83/84, a total of 131,946 analyses were performed in support of Task #3, with the biogeochemical sites supplying the bulk of the workload.

Several developments occurred which lessened delays to analysis, as well as the quality of the analyses. These included a preconcentration preparation step for the analysis of metals in throughfall, stemflow, lysimeter and column leachate samples. Also, a new particle size analyser was acquired, which should reduce the time and effort required for this analysis, which is currently done with a manual procedure.

TASK #4 - SOCIOECONOMIC INVESTIGATIONS

Biological, chemical and physical studies of acid deposition have not yet precisely defined all relevant cause and effect relationships. Consequently, there is a great deal of uncertainty about the effects and damages being caused by acid deposition, their extent, their magnitude and their relative importance. Despite this uncertainty, plans and choices must be made regarding abatement programs and control strategies. Socio-economic tools and principles can help to define, evaluate and implement such programs. Socio-economic investigation also helps to define the relevant bio-physical information needed for policy deliberations.

For example, in the absence of reliable information on the benefits of an acid rain control program, a "cost-effective" program can be devised to achieve a target deposition rate. A tentative deposition objective of 20 kilograms of wet sulphate per hectare-year has been proposed by Canadian scientists. It is believed that reductions to this level will prevent acidification in all but the most sensitive aquatic ecosystems. Using tools and methods described below, various abatement programs for eastern Canada and the U.S. can be defined which will achieve this objective at the least total costs for all concerned.

In the meantime, models have been developed that permit us to employ the dose-response information that is available as well as other data and assumptions to estimate acid rain effects and the benefits of control programs. The results of these exercises can help authorities to make more explicit comparisons between the benefits and costs of these programs.

Given the uncertainties of the effects of acid deposition and the high costs of the control programs, as well as the international nature of the issue, it is unlikely that target deposition rates such as the 20 kg per hectare-year will be accepted by the U.S. and other parties without more explicit comparisons with program costs.

A. Damages and Benefits Studies

Three socioeconomic studies were undertaken to develop the methodology needed to identify the damages of acid rain and to estimate the benefits of its control.

These studies are described in a recently released report "The Economics of Acid Precipitation: A Review of Socio-economic Methods to Assess Acid Deposition Effects" which presents a summary of the methodologies developed by consultants retained by the Ministry of the Environment to estimate monetary values of some of the biophysical effects of acid rain.

Computer models have been developed which estimate the potential biological effects of acid precipitation and their economic implications for certain receptor categories. These models permit updating inventory and dose-response data or changing assumptions and deposition scenarios to assess their consequences. The dose-response relationships and other aspects of these models are being reviewed and revised as necessary.

The methodologies that have been developed to estimate the dollar value of potential damages ascribed to acid precipitation were reviewed with representatives from West Germany. Efforts are underway to set up a more formal exchange of technical information.

B. Costs of Abatement and Mitigation

The recommendations made by the Ontario/Canada Task Force on Inco and Falconbridge in its final report were reviewed by appropriate provincial Ministries and federal Departments. As well, responses were received from the two Companies who basically disagreed with the cost estimates, insisting that they were underestimated in most cases.

Data continued to be compiled for the Ontario Hydro thermal power plants, the Algoma Steel plant at Wawa, the petrochemical refineries in Southern Ontario and mobile source emissions. Continued investigations were made of control costs. These cost data are continually refined for industries affected in both Ontario and the United States since they serve as input into the 'screening model'. (See Task 4C).

C. Development of an Abatement Strategy

Information from the above two tasks is needed to develop a cost-effective abatement strategy for the province, not only as a component of an overall eastern Canadian abatement program, but also as part of a strategy to curtail acid rain in eastern North America.

One of the tools developed to aid in the formation and evaluation of abatement strategies has been the "screening model". It is designed to identify or 'screen out' those strategies which are both efficient in terms of minimizing control costs and effective in terms of achieving the desired deposition objectives.

This model was used in the ongoing analysis of various abatement scenarios in order to identify options for emissions reductions in eastern Canada.

The model is now undergoing sensitivity analyses to changes in base emissions, discount rates and LRTAP transfer coefficients. Also, a peer review of the model is being set up.

In addition to setting objectives, an effective environmental strategy must assess the available policies and legal instruments to induce polluters to implement control measures.

Therefore, an Intergovernmental Work Group which was established in FY 1982/1983 has been undertaking a thorough review of various implementation policy options including emission charge schemes, tradeable emission permits and various forms of financial assistance to determine their suitability to the LRT issue with specific reference to an eastern Canadian abatement strategy.

With respect to the area of strategy development, a major step was taken by the federal and eastern provincial Environment Ministers on March 6, 1984. The Ministers agreed at that time to an SO_2 emissions cap of 2.3 million tonnes per year east of the Manitoba-Saskatchewan border to be achieved by 1994.

It had been previously determined that a ceiling of 2.3 million tonnes per year, together with appropriate U.S. action, would enable us to reduce deposition to no more than 20 kg of wet sulphate per hectare year in most sensitive areas in eastern Canada.

Therefore, the March 6 agreement means that eastern Canada will move ahead unilaterally to accomplish its part of the necessary reductions. The precise allocation of the reductions needed to reach the new Eastern Canada cap of 2.3 million tonnes of SO_2 is under development.

Since concomitant U.S. action is still needed to reach the deposition target, it is hoped that this demonstration of the Canadian commitment will eventually motivate U.S. control actions.

TASK #5 - LEGAL INITIATIVES

A. Provincial Initiatives

Ontario was the first jurisdiction in North America to mandate emission controls based solely on the acid rain phenomenon and not on ambient air quality.

In 1980, a Regulation was issued to Inco Limited, Ontario's largest SO_2 source, to reduce the emissions from its Copper Cliff smelter to 1,769 tonnes per working day by January 1983.

In 1981, a Regulation was issued to Ontario Hydro to reduce its system-wide SO_2 emissions to 390,000 tonnes by January 1986 and to further reduce those emissions to 260,000 tonnes by 1990. (Emissions in 1983 were 438,000 tonnes.) This Regulation does not specify technology. The primary mechanism which will reduce SO_2 emissions from the utility is the replacement of coal-fired electrical generation with nuclear generation. Also, greater use will be made of washed and low-sulphur coal.

To date, no other Regulations have been issued. However, once Ontario's contribution to the eastern Canadian reduction program is determined, we will have to review all major sources in the province, including Ontario Hydro and Inco, to meet our portion of the agreement.

B. International Initiatives

Ontario's initial involvement in U.S. legal proceedings occurred in 1981. On March 12, 1981, the Ontario Ministry of the Environment filed a legal intervention with the U.S. Environmental Protection Agency which requested the E.P.A. to reject proposals from six states for a relaxation of SO_2 emission limits governing 18 power plants in Ohio, Michigan, Indiana, Illinois, West Virginia and Tennessee.

On March 27, 1981, Ontario expanded its intervention to include two large power plants near Cleveland, Ohio. The current status of the 20 S.I.P. revisions that were the subject of Ontario's submission is as follows:

Approved	8
Proposed Disapproval	1
Decision Pending	1
No Action	1
Original Proposal Disapproved: Revised Proposal Submitted; Decision Pending	4
Original Proposal Disapproved: Revised Proposal to be Submitted	2

Original Proposal Conditionally Approved: Revised Proposal Submitted; Decision Pending 3

Throughout FY 1983/1984, Ontario continued to express its concern to the U.S. Environmental Protection Agency and/or individual State Agencies when relaxation of State Implementation Plans (S.I.P.s) for SO_2 were being considered.

In order to ensure that we were kept informed of all such proposed relaxations, we requested the assistance of Canadian Consulates in the U.S. for early notification of proposed relaxations. This assistance was readily granted.

On May 10, 1983, Ontario submitted a letter in opposition to the E.P.A.'s proposed approval of a request by the Indiana Air Pollution Control Board for a revision to its SO_2 State Implementation Plan for the Indiana-Michigan Electric Company Breed Plant. The revision, submitted in the form of the State operating permit for Breed, would relax the state enforceable emissions limit for this plant from 6.0 lbs of SO_2 per million Btu heat input to 9.57 lbs per million Btu. This operating permit also contained a condition which would grant a "special temporary exemption" from Indiana's opacity regulations for startup and shutdown.

On May 27, 1983, the U.S. Environmental Protection Agency published a proposed rulemaking in the Federal Register to disapprove the Breed relaxation because the State had not demonstrated that the National Ambient Air Quality Standards (NAAQS) would be protected during periods of excess emissions occurring at startup and shutdown. On July 27, 1983, Indiana withdrew its request that an opacity variance be approved as a revision to the S.I.P.

Therefore, E.P.A. subsequently has withdrawn its May 27, 1983 disapproval and now proposes approval of the SO_2 S.I.P. revision.

Ontario's second intervention for this period included both a written and verbal presentation in opposition to the Consumers Power Company request to the Michigan Air Pollution Control Commission to delay bringing its J.H. Campbell and B.C. Cobb power plants into compliance with the Michigan "one percent or equivalent sulphur in fuel" rule. Ministry representatives appeared at the public hearing held on November 28, 1983 in order to voice Ontario's concern with respect to this issue. The Commission, after a lengthy public hearing where arguments were given on both sides, eventually denied the Company's request. A similar decision was reached the previous year by this Commission with respect to Detroit Edison's Monroe Power Plant. Ontario also appeared at the Commission Hearing to consider this request.

All of the above S.I.P. relaxations fall under Section 110 of the U.S. Clean Air Act which ensures that the states are meeting the National Ambient Air Quality Standards for major pollutants. Sections 126 and 115 are especially relevant to Ontario and Canada when addressing the long range transport of air pollutants issue. Section 126 deals with interstate pollution and Section 115 deals with international pollution.

In June of 1981, Ontario appeared at a Section 126 Hearing of the U.S. E.P.A. to offer technical evidence in support of petitions by the States of New York and Pennsylvania that emissions from the Midwest States were impacting on their environments. To this date, the E.P.A. has not made a ruling on this Section 126 petition.

Therefore, these States and several others, as well as various environmental organizations, have filed a legal suit against the U.S. Environmental Protection Agency that i) the Administrator has violated his mandatory duty under Section 126 to issue a final decision on the petitions regarding interstate air pollution by the deadline (within sixty days) specified in the statute and ii) that the Administrator has violated his mandatory duty to determine which states are contributing to air pollution which endangers the public health and welfare of Canada and to give notice to the Governors of such States to revise their State Implementation Plans in order to prevent or eliminate harm.

Ontario is closely monitoring the legal proceedings of this suit, and will be especially interested in the developments of the Section 115 proceedings.

TASK #6 - PUBLIC RELATIONS INITIATIVES

A. Provincial Initiatives

Several public opinion polls and the large number of information requests received by various Branches of the Ministry continue to indicate that acid rain is an issue of concern to the Ontario public. In response to this concern, public relations activities have been initiated to keep the Ontario public informed of any developments in this area.

Since the Muskoka-Haliburton area is extremely sensitive to acid precipitation and since it is a prime recreation area in southern Ontario, many intensive research activities are underway there. The focus of this research has led to the establishment of a major research facility at Dorset. The development of this facility has taken several years, however, July 1983 marked the official opening of the centre. This opening was attended by local officials and citizens and was hosted by the Honourable Keith Norton, then the Ontario Environment Minister.

One activity to increase public awareness and understanding of the acid rain problem is the release of a weekly acid rain pH report which is prepared jointly by Environment Ontario and Environment Canada.

This report is issued by Environment Canada every Tuesday and it summarizes the pH of rain and snow events which have occurred over the preceding seven days. The following five locations are monitored:

1. Kejimkujik National Park, Southwest Nova Scotia.
2. Forêt Montmorency, Southcentral Québec.
3. Chalk River, Southeastern Ontario.
4. Longwoods, Southwestern Ontario.

(The above sites are operated by Environment Canada.)

5. Dorset Field Station, Muskoka, Ontario. (Operated by Environment Ontario.)

Also, during the past year, several Fact Sheets on acid rain were updated and new ones were prepared. Work proceeded on the update of the acid rain videotape and brochure.

These fact sheets and audiovisual aids provide valuable background information for events such as Open Houses and for responses to requests for general information on acid rain. The APIOS program also produces an 'Acid Sensitivity Survey of Lakes in Ontario' which is updated annually. In 1983, the survey presented data on over 4,000 lakes throughout the province. This information has proven valuable in responding to requests from cottagers for information concerning the status of their lakes.

B. United States Initiatives

In the U.S., the last year has been a very dynamic one with respect to the acid rain issue.

In the Spring of 1983, the U.S. E.P.A. underwent severe criticism. Following the resignation of E.P.A. Administrator Anne Gorsuch Burford, Mr. William Ruckelshaus was appointed Administrator. He was charged with the task of reviewing the acid rain issue and coming up with a proposal for the President.

Many agencies were hopeful that this change within the Reagan Administration would result in some positive control actions and Mr. Ruckelshaus did attempt to push through a control program. Unfortunately, it had neither the support of the environmental agencies nor of the industries and was strongly opposed by Mr. David Stockman, Office of Management and Budget, who charged that the costs of such a control program were excessive.

Some hope still remained that the President would offer a control program in his State of the Union address in January 1984, especially since 1984 is an election year in the U.S. These hopes were soon dashed by the President's announcement that his only action in the acid rain area at this time was increased research.

Throughout the year, however, opinion polls indicated that public awareness of the acid rain issue was increasing in the U.S. and that there was support for more controls even if they meant higher electricity rates. A wide variety of interest groups within the U.S. continued to reject the official "research-only" position, and called for immediate action on both sides of the border.

Even though general awareness of the acid rain issue was increasing, several presentations by Ontario representatives before U.S. audiences in both pro-control and anti-control states indicated that comprehension of the issue and specifically Ontario's efforts and position still required clarification.

The Ministry has, therefore, continued its activities to inform the U.S. of the nature and extent of the problem in Ontario in order to obtain support for an abatement program. This objective was met through continued showings of our acid rain film at the Canadian Consulate Offices in the U.S. and through attendance and participation in relevant U.S. acid rain activities. (See Appendix II.) By April 1, 1984, the film 'Crisis in the Rain' was seen by 134,000 viewers in direct showings and four million via TV in Canada and United States (cumulative total since the APIOS program started).

Other activities included appearance by Ministry staff at several Hearings on this issue, such as Senator

Durenberger's Hearing on Acid Rain for the U.S. Senate Environment and Public Works Committee.

Furthermore, a tour of the Dorset field site was arranged for the U.S. National Acid Precipitation Assessment Plan Task Force as part of its annual meeting with the Canadian Federal/Provincial LRTAP Research and Monitoring Committee to discuss joint Canada/U.S. research projects.

Then, early in 1984, a visit was made by the Honourable A. Brandt to Washington, D.C. at which time he met with representatives of the U.S. Congress, industry, environmental groups and media to emphasize Ontario's concerns and hopes for a commitment to reduce harmful pollutants.

The past year has marked increased international cooperation on this issue with Canada being a prime participant in European activities on acid rain. Ontario was well represented at the Canada-Europe Ministers Conference in Ottawa, March 20-21, 1984 at which the participating countries declared their intention to reduce SO_2 emissions by 30%. It is hoped the growth of international cooperation on this issue between the many countries concerned about acid rain will ultimately result in a commitment to reduce emissions on all fronts.

CONCLUSIONS

Long range transport of air pollutants including damage caused by their deposition is a complex problem and not easily understood.

However, the case for control of sulphur dioxide emissions to protect surface waters is quite strong and while the case for emission controls to protect forests is not as scientifically well developed, there is consensus that air pollution is involved in the recent widespread forest decline.

As a result, Canada has initiated a unilateral SO_2 control program even though it is known that this measure will not be fully protective of the environment without control action by the United States.

However, experience has shown that, over time, virtually every industrialized country has discovered serious damage to surface waters, forests and buildings within their boundaries. Public awareness of these damages has resulted in control programs which benefit neighbouring countries as well.

As a result, Ontario, in cooperation with other affected jurisdictions, must rapidly improve the scientific data base and ensure that our research results are adequately communicated to our counterparts in the United States.

We must also emphasize that we are supportive of least cost targeted emission reduction schemes which allow each jurisdiction the flexibility of implementing controls in a cost-effective way by the means most suitable to their own conditions.

In Canada, we have decided to implement a significant, yet manageable, SO_2 reduction program while research on environmental effects continues. Results from this ongoing research will better define our ultimate abatement needs. However, by starting to implement controls now, as much time as possible is provided to industries involved to make the required reductions in emissions with a high degree of flexibility and some cost savings.

APPENDIX I

INTERNATIONAL COOPERATIVE PROJECTS

Project Title	Participating Agencies	Purpose
Acid Deposition and Oxidants Model (Super Model)	Environment Ontario Atmospheric Environment Service Umweltbundesamt (West Germany) Environment Québec State of Minnesota State of New York	To improve predictions of source/receptor relationships, i.e. what areas are affected by what sources? Also, to evaluate various emission control scenarios.
Aluminum Biogeochemistry in Forested Watersheds	Electric Power Research Institute Environment Ontario Environment Canada United States West Germany Norway Sweden United Kingdom	To identify and quantify the release, transport and toxicity of aqueous aluminum in the natural environment. Aluminum is toxic to both fish and trees.
Cross Appalachian Tracer Experiment (CAPTEX)	Environment Ontario Atmospheric Environment Service National Oceanic and Atmospheric Administration Environmental Protection Agency Electric Power Research Institute	To provide tracer data to validate and improve long range transport models, and to gain a better understanding of the dispersion and transport of pollutants over large distances. Several tracer releases were made in 1983 from Dayton, Ohio and Sudbury, Ontario; the results of the experiment are still being analysed.

Project Title	Participating Agencies	Purpose
Dry Deposition Intercomparison Measurements	Environment Ontario Atmospheric Environment Service Illinois State Water Survey National Aeronautical Establishment U.S. Department of the Interior National Oceanic and Atmospheric Administration Environmental Protection Agency Argonne National Laboratory Oregon State University	To improve quality control and comparability of Canada/U.S. results.
Economic Commission for Europe - Subgroup on Environmental Effects of Sulphur Compounds	Canada, West Germany, United Kingdom, United States, Norway, Sweden, Finland, the Netherlands	To prepare documents in support of controls of SO_2 and other pollutants throughout the E.C.E. countries.
Effects of Acidification on Calcium and Magnesium Uptake by Trees	Environment Ontario Federal Research Centre for Forestry and Forest Products (Hamburg, Germany)	In the planning stages.
Fisheries Loss Assessment Program	NAPAP Environment Ontario Ontario Ministry of Natural Resources EPRI Environment Canada	To assist NAPAP in the design of a program to assess fisheries loss in the U.S. related to acidic deposition.

Project Title	Participating Agencies	Purpose
Forest Tours (1984/1985) (in planning stages)	West Germany, Norway, Sweden, United States, Canada	Experts will tour damaged forest areas in North America and Europe in order to determine the cause(s).
Human Health Effects Related to Aquatic Effects of Acid Deposition	EPA Environment Ontario Various State Health Agencies	MOE has been invited to sit on a Committee of experts to determine the exact nature and extent of these human health effects.
Informal Calibrated Watershed Modelling Group	Environment Ontario Environment Canada United States Norway Sweden	To compare results and ideas on watershed studies. The work defines effects of acid rain and develops target loadings to prevent damage.
Interlaboratory Quality Assurance	Government and private laboratories in Canada and the U.S. (over 50 labs involved, including MOE)	To ensure the validity and compatibility of all data collected under LRT programs in North America.
Lake Acidification Mitigation Program	EPRI Clarkson College Environment Ontario	MOE has been requested to provide advice and information concerning lake liming projects.

Project Title	Participating Agencies	Purpose
Massive Atmospheric Tracer Experiment	EPRI EPA Environment Canada Environment Ontario	MOE has been asked to assist in the design of a massive tracer experiment for empirically determining source-receptor relationships.
National Surface Water Survey	EPA Environment Ontario Environment Canada	To characterize current water chemistry of lakes and streams in five U.S. Regions. MOE has been requested to assist in the development of the survey design.
Ontario/Minnesota Agreement	Ontario Minnesota	To exchange information on acid rain; to cooperate on specific projects (atmospheric modelling, RAINS - NIVA, aquatic effects in a medium deposition area).
Ontario/NADP Intercomparison Study - Ely, Minnesota	Ontario National Atmospheric Deposition Program	To improve comparability of data.
Ontario/New York Agreement	Ontario New York	To exchange information on acid rain; to cooperate on specific projects (deposition measurements and comparisons, possibly some mercury deposition and lake liming studies).

Project Title	Participating Agencies	Purpose
Rain Acidity Interlaboratory Study of Damage to Agricultural Crops	Environment Ontario Boyce Thompson Institute Argonne International Laboratory Corvallis Environmental Research Laboratory Oakridge National Laboratory Brookhaven National Laboratory	To measure the effects of different pH's on crops and to standardize techniques and procedures.
Reversing Acidification in Norway - NIVA	Environment Ontario Norway Sweden Environment Canada	To test hypotheses on watershed sensitivity and to measure watershed response to reductions and increases in acid loadings. This issue has been recently raised by the U.S. E.P.A. as an impediment to designing a control program.

APPENDIX II

A.P.I.O.S. PARTICIPATION IN ACID RAIN ACTIVITIES

FISCAL YEAR 1983/1984

Date	Activity
April 12-14, 1983	International Conference on Long Range Transport Models for Photochemical Oxidants and their Precursors, Research Triangle Park, N.C.
April 25-29, 1983	Workshop on Methodologies and Information Needs for Broad-scale Assessment of the Effects of Acid Deposition. Leetown, West Virginia. U.S. Interagency Task Force on Acid Precipitation.
April 29, 1983	Tour of Air Resources Branch facilities for Dr. Pankrath with the Umweltbundesamt, West Germany.
May 25-26, 1983	CAPTEX Planning Meeting, Research Triangle Park, N.C.
June 2-3, 1983	40th Eastern Snow Conference, Ottawa.
June 14-17, 1983	Conference on Acid Rain and Forest Resources, Québec City.
June 16 and 17, 1983	Tour of Dorset site and Air Resources Branch facilities for Swedish journalist (Johnson).
June 21 and 22, 1983	Tours of biogeochemical site, greenhouse and soil laboratory for Dr. Herbsleb with the Bundesministerium für Ernährung, Landwirtschaft and Forsten in West Germany.
June 20-24, 1983	6th North American Forest Soils Conference, Knoxville, Tennessee.
July 13, 1983	Briefing Session for German delegation.
July 6-8, 1983	Review of EPA-Duluth-Environmental Research Laboratory Program on Acid Deposition, Duluth, Minnesota.
July 17-22, 1983	Engineering Foundation Conference - "Effects of Atmospheric Chemistry and Transport - Acid Rain", Henniker, New Hampshire.

Date	Activity
July 18-19, 1983	Workshop on Sampling and Analyses Protocol for Biological Characteristics of Lakes and Streams Affected by Acidic Deposition. Cornell University, New York. U.S. Environmental Protection Agency.
August 19, 1983	American Fisheries Society Annual Meeting, Milwaukee, Wisconsin.
August 22, 1983	Meeting with Dr. K. Domsch with the Department of Soil Biology, Braunschweig, Germany to discuss areas of cooperative research between Ontario and Germany.
August 25, 1983	Presentation to Senator Durenburger - Roseville, Minnesota.
August 28 - September 2, 1983	Commission on Atmospheric Chemistry and Global Pollution (CACGP) Symposium on Tropospheric Chemistry with Emphasis on Sulfur and Nitrogen Cycles and the Chemistry of Clouds and Precipitation, Oxford, England.
September 30, 1983	Meeting with Dr. E. Niesslein of Germany - Toronto, Ontario.
October 3, 1983	Water Pollution Control Federation Annual Conference, Atlanta, Georgia.
October 4-5, 1983	Symposium on Air Pollution and the Productivity of the Forest, Washington, D.C.
October 17-19, 1983	Economic Commission for Europe - Effects of Sulphur Compounds on Aquatic Ecosystems Meeting, Geneva, Switzerland.
October 19, 1983	Agrometeorological Workshop "Role of Long Range Transport and Weather in Agriculture", Guelph, Ontario.
October 26, 1983	New York Conference on Atmospheric Deposition, Albany, New York.
November 3, 1983	Missouri Electric Cooperative Association Meeting, Lake Ozark, Missouri.
November 21-25, 1983	Economic Commission for Europe - Effects of Sulphur Compounds on Terrestrial Ecosystems Meeting, Geneva, Switzerland.

Date	Activity
December 1, 1983	American Fisheries Society Meeting, Thunder Bay, Ontario.
December 6, 1983	Joint Meeting of Pittsburgh Chapters of American Institute of Chemists and American Chemical Society, Pittsburgh, Pennsylvania.
December 7, 1983	U.S. Department of Energy, Pittsburgh Energy Technology Centre, Pittsburgh, Pennsylvania.
December 28-29, 1983	Annual Meeting of the American Economics Association, San Francisco, California.
January 4, 1984	Canadian Society of Limnologists Meeting, Ottawa, Ontario.
January 5-6, 1984	MATEX (Massive Atmospheric Tracer Experiment) Planning Meeting, Westlake Village, California.
January 6, 1984	Acid Rain '84: A Citizens' Conference to Stop Acid Rain, Manchester, New Hampshire.
January 10-11, 1984	Workshop on Accuracy in Air Pollutant Emissions Data Bases, Atlanta, Georgia.
March 5-9, 1984	Meeting of the Economic Commission for Europe Subcommittee on Effects of Sulphur on the Environment, Geneva, Switzerland.
March 6-7, 1984	EPA Peer Review Meeting for U.S. Acid Precipitation Agricultural Program, Urbana, Illinois.
March 15, 1984	Workshop on Precipitation Chemistry Analysis and Quality Control/Assurance Procedures, Toronto, Ontario.
March 20-21, 1984	Canada-Europe Ministers Conference, Ottawa, Ontario.
March 26-28, 1984	"First International Conference on Acid Rain": Regulatory Aspects and Engineering Solutions, Washington, D.C.
March 26-28, 1984	Workshop on Understanding Processes and Modelling Acidification in Calibrated Watersheds, Oak Ridge, Tennessee.

APPENDIX III

A.P.I.O.S. REPORTS AND SUBMISSIONS

1984

Annual Program Report - Fiscal Year 1982/1983. APIOS Report No. 001/84.

Cumulative (28 Day) Precipitation Chemistry Listings - January 5, 1982 - January 4, 1983. APIOS Report No. 003/84.

The Economics of Acid Precipitation: A Review of Socio-Economic Methods to Assess Acid Deposition Effects. APIOS Report No. 006/84. April, 1984.

1982 Daily Ambient Air Concentration Listings. APIOS Report No. 004/84.

1982 Daily Precipitation Chemistry Listings. APIOS Report No. 002/84.

Quality Assurance Plan - APIOS Deposition Monitoring Program.

1983

Acid Sensitivity Survey of Lakes in Ontario. APIOS Report No. 001/83.

Annual Statistics of Concentration and Deposition - Cumulative Precipitation Monitoring Network, 1981. R.W. Kirk. August 1983. APIOS Report No. 008/83.

Annual Statistics of Concentration and Deposition - Daily Ambient Air Monitoring Network, 1981. R.W. Kirk. September 1983.

APIOS Daily Precipitation Chemistry Listings, July 15, 1980 - December 31, 1981. Revised Edition January 1983.

APIOS Monthly/28 Day Cumulative Precipitation Chemistry Listings, June 1980 - December 1981. March 1983.

Daily Ambient Air Concentration Listings, July 25, 1980 - December 31, 1981. May 1983.

Meteorological Analysis of Precipitation Event Sampling Data (July 1980 - December 1981). J. Kurtz. June 1983.

1983 (continued)

1981 Summary Statistics of Observed Concentration and Deposition: Daily Precipitation Monitoring Network. R.W. Kirk and W.H. Chan. June 1983.

Precipitation Concentration and Wet Deposition Fields of Pollutants in Ontario, September 1980 to December 1981. W.H. Chan, A.J.S. Tang and M.A. Lusis. June 1983.

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Consumers Power Company Request to Delay Bringing its J.H. Campbell and B.C. Cobb Power Plants into Compliance with the Michigan "One Percent or Equivalent Sulphur in Fuel" Rule. Grand Haven, Michigan. November 28, 1983.

Studies of Lakes and Streams: Pukaskwa National Park. J. Sutton, L. Maki, K.J. Deacon and G.W. Ozburn. API 003/83.

Water Quality-Crustacean Plankton Relationships in Northeastern Ontario Lakes. W. Keller and J.R. Pitblado. API 002/83.

1982

Acid Sensitivity Survey of Lakes in Ontario. APIOS 003/82. Summer 1982.

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. Reprint with supplementary insert - Summer 1982.

Daily Precipitation Chemistry Listings and Statistical Summaries July 15, 1980 - December 31, 1981. APIOS 001/82. Summer 1982.

The Economics of Acid Precipitation: Ontario's Socio-economic Research Program. API 007/82. December 1982.

Experimental Neutralization of a Small, Seasonally Acidic Stream Using Crushed Limestone. API 004/82. Summer 1982.

Lagrangian Model of the Long Range Transport of Sulphur Oxides. API 008/82. Fall 1982.

Monitoring of Lake Superior Tributaries, 1980-1981. API 009/82. Fall 1982.

An Overview: The Cumulative Wet/Dry Deposition Network. December 1982.

An Overview: The Event Wet/Dry Deposition Network. API 002/82. Summer 1982.

1982 (continued)

The Province of Ontario. Presentation to the Michigan Air Pollution Control Commission in Opposition to the Detroit Edison Request to Delay Bringing its Monroe Power Plant into Compliance with the State of Michigan "1% or Equivalent Sulphur in Fuel" Rule. Monroe, Michigan. June 30, 1982.

Report of the Ontario/Canada Task Force for the Development and Evaluation of Air Pollution Abatement Options for Inco Limited and Falconbridge Nickel Mines, Limited in the Regional Municipality of Sudbury, Ontario. December 21, 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Muskoka-Haliburton Area of Ontario, 1980. API 006/82. Fall 1982.

A Synoptic Survey of the Acidity of Ground Waters in the Sudbury Area of Ontario, 1981. API 005/82. Fall 1982.

1981

Acid Sensitivity Survey of Lakes in Ontario. API 002/81. March 1981.

An Annotated Bibliography: Terrestrial Effects of Acidic Precipitation. APIOS 003/81. July 1981.

Chemical, Microbiological and Physical Interactions of Acidic Precipitation Within a Lake and its Drainage Basin. API 004/81. July 1981.

Lakewide Odours in Ontario and New Hampshire Caused by Chrysochromulina Breviturrita Nich. (Prymnesiophyceae). API 001/81. 1981.

The Province of Ontario. Presentation to the Air Pollution Control Board of the State of Indiana in Opposition to the Indiana-Kentucky Electric Generating Station Petition to Operate With an Increase in its Sulphur Dioxide Emissions to 7.52 pounds of SO_2 per Million BTU's of Heat Input. Indianapolis, Indiana. October 7, 1981.

The Province of Ontario. A Submission to the United States Environmental Protection Agency Hearing on Interstate Pollution Abatement. Washington, D.C. June 19, 1981.

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1981 (continued)

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1980

Acidic Precipitation in South-Central Ontario: Analysis of Source Regions Using Air Parcel Trajectories. J. Kurtz and W. Scheider. MOE Report, May 1980.

Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of Inco Ltd. in Sudbury. W.A. Scheider, D.S. Jeffries and P.J. Dillon. May 1980.

The Case Against the Rain: A Report on Acidic Precipitation and Ontario Programs for Remedial Action. October 1980.

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Chan, W.H., R.J. Vet, M.A. Lusis and G.B. Skelton. (1982). Size Distribution and Emission Rate Measurements of Particulate in the Inco 381 M Chimney and Iron Ore Recovery Plant Stack Plumes, 1979-80. Report ARB-TDA-62-80.

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